



US009094863B2

(12) **United States Patent**  
**Nakajima et al.**

(10) **Patent No.:** **US 9,094,863 B2**  
(45) **Date of Patent:** **Jul. 28, 2015**

(54) **RADIO COMMUNICATION DEVICE,  
METHOD, AND PROGRAM THAT  
CALCULATE TRANSMISSION TIME BASED  
ON DATA RATE**

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(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 995 days.

(21) Appl. No.: **12/343,785**

(22) Filed: **Dec. 24, 2008**

(65) **Prior Publication Data**  
US 2009/0196364 A1 Aug. 6, 2009

(30) **Foreign Application Priority Data**  
Dec. 28, 2007 (JP) ..... 2007-339941

(51) **Int. Cl.**  
**H04W 28/06** (2009.01)

(52) **U.S. Cl.**  
CPC ..... **H04W 28/065** (2013.01)

(58) **Field of Classification Search**  
None  
See application file for complete search history.

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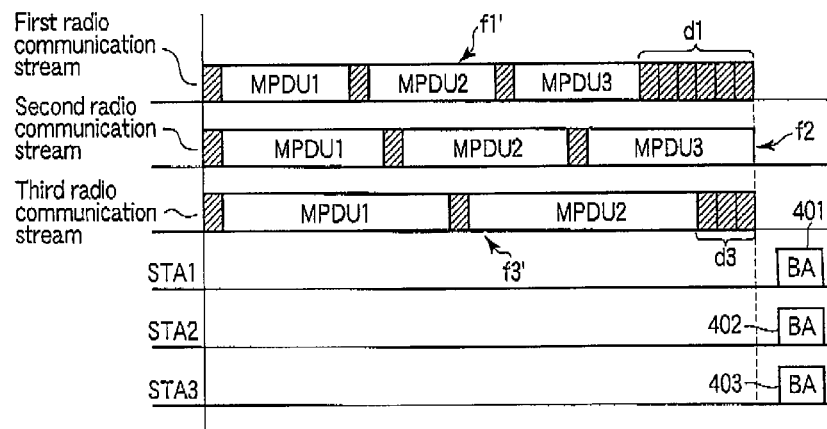
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(57) **ABSTRACT**

A radio communication method stores a plurality MAC frames for each of a plurality of destinations. The method decides the longest transmission time of transmission times needed to transmit the plurality of MAC frames to each of the plurality of destinations within a fixed period. The method generates a plurality of physical frames for the plurality of destinations to transmit them at the same time by connecting the plurality of MAC frames and adding additional information to each connected MAC frame so as to be a frame length equivalent to a transmission time equal to the longest transmission time.

**13 Claims, 7 Drawing Sheets**



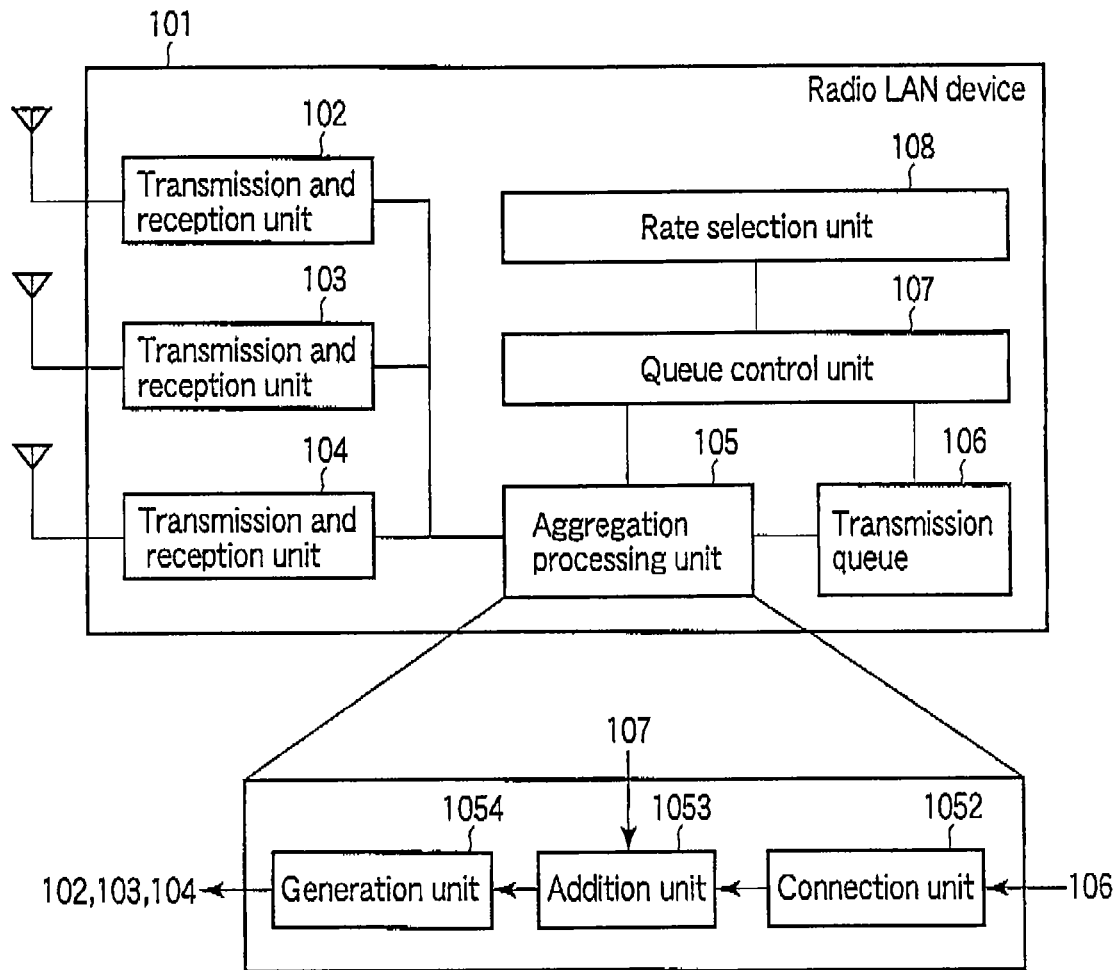


FIG. 1

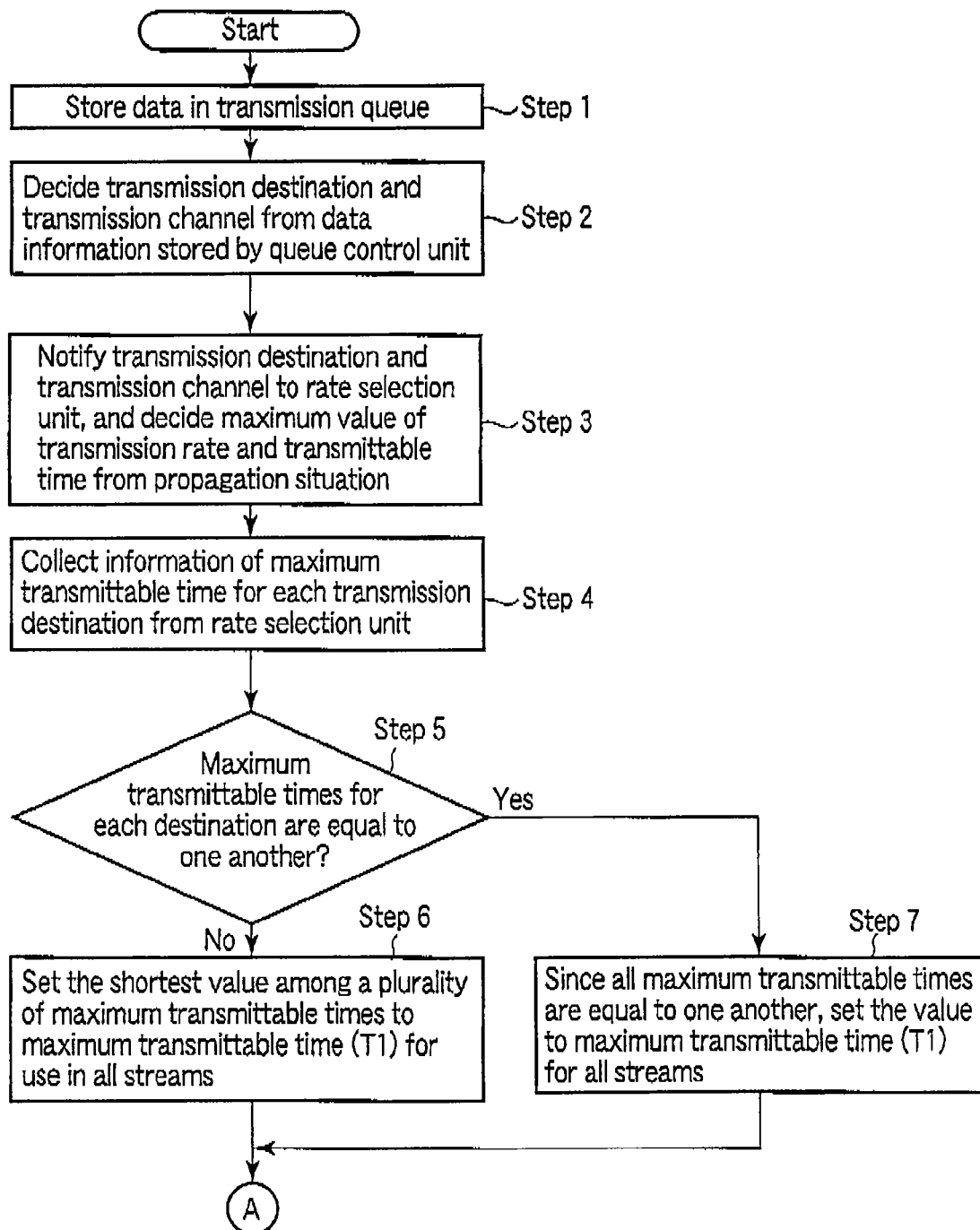


FIG. 2A

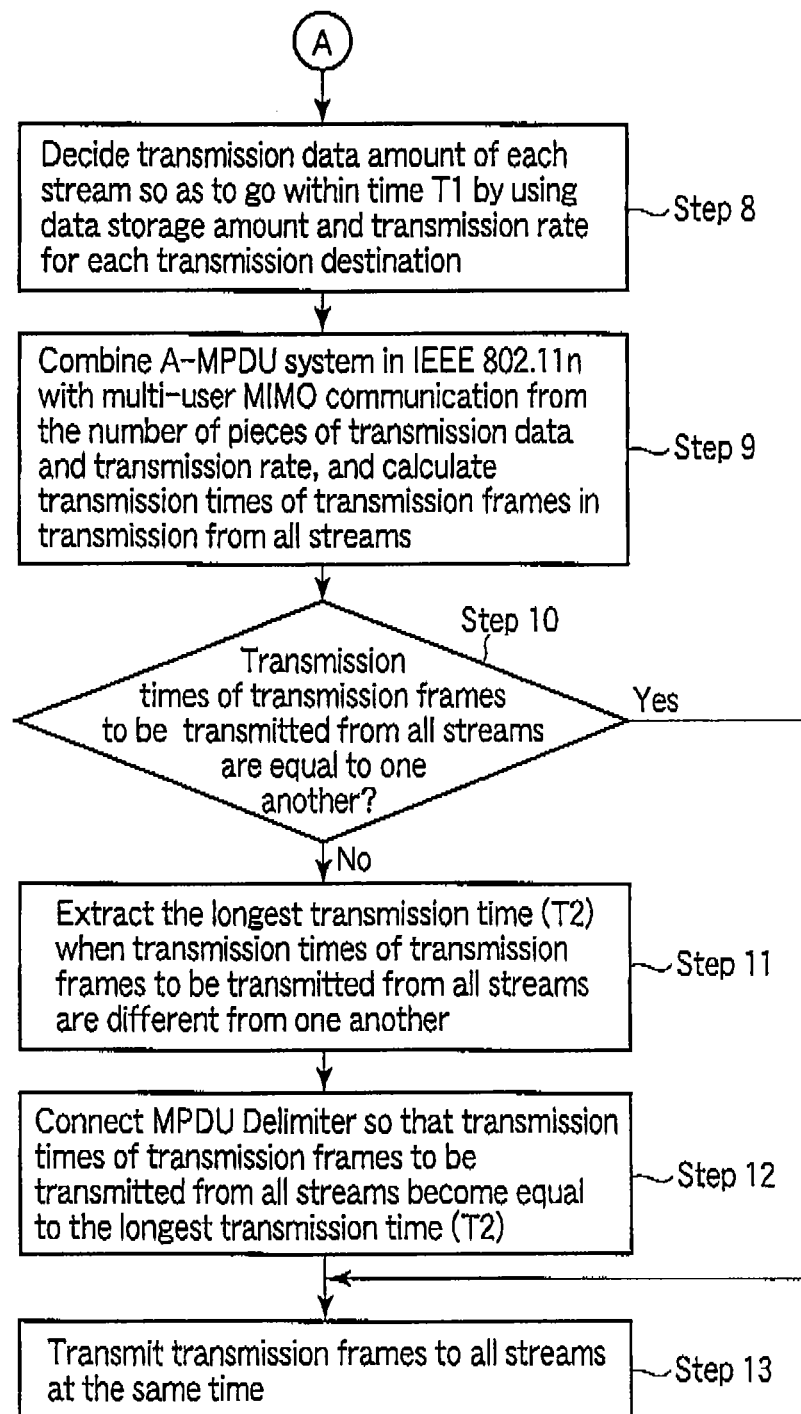


FIG. 2B

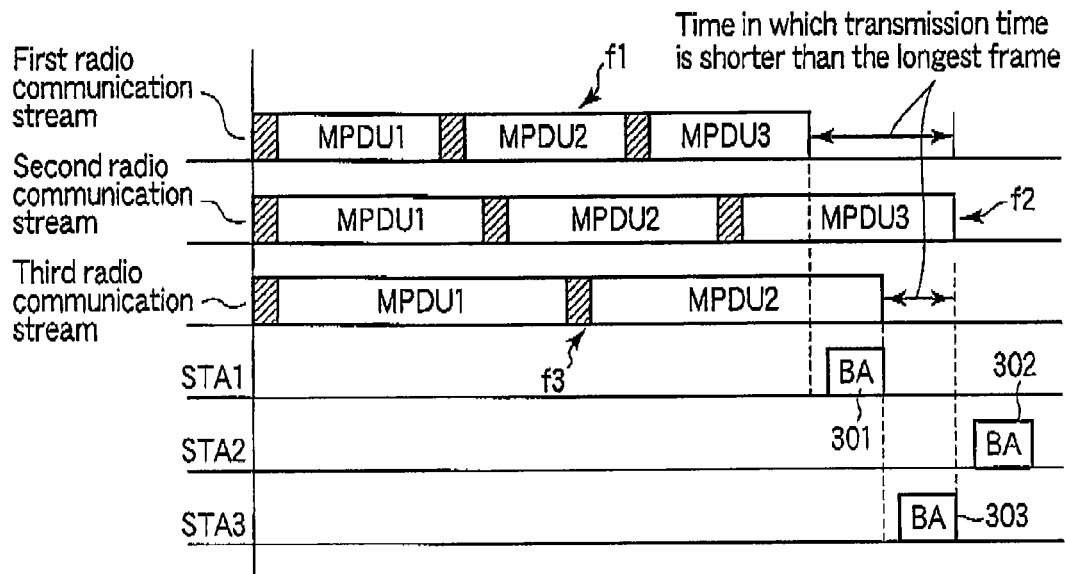


FIG. 3

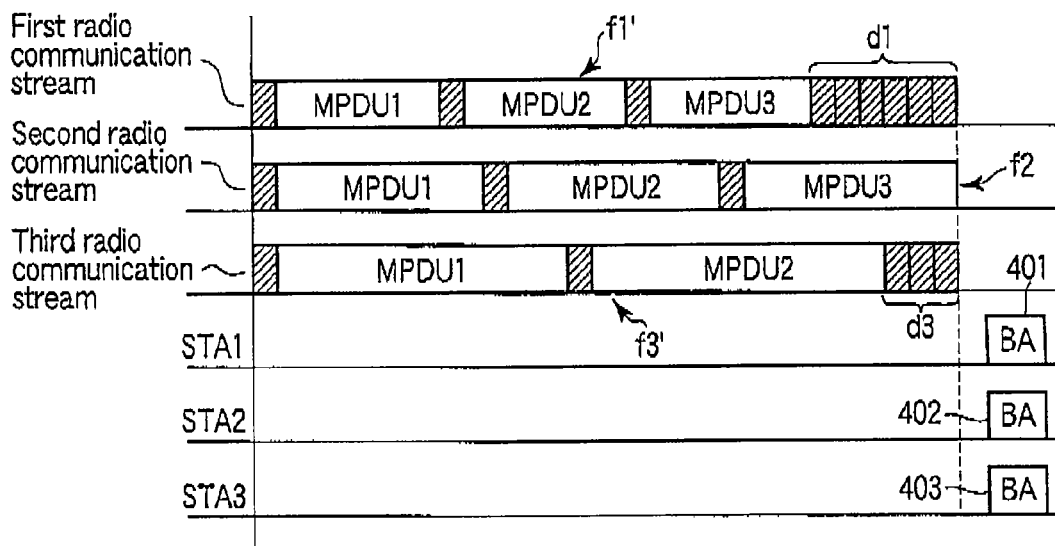


FIG. 4

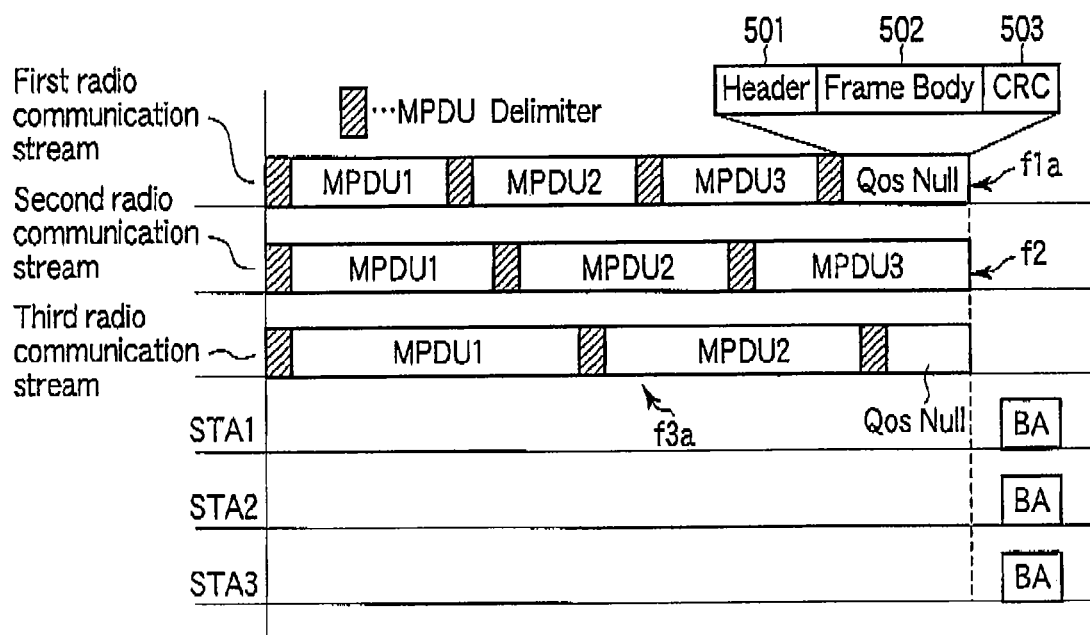


FIG. 5

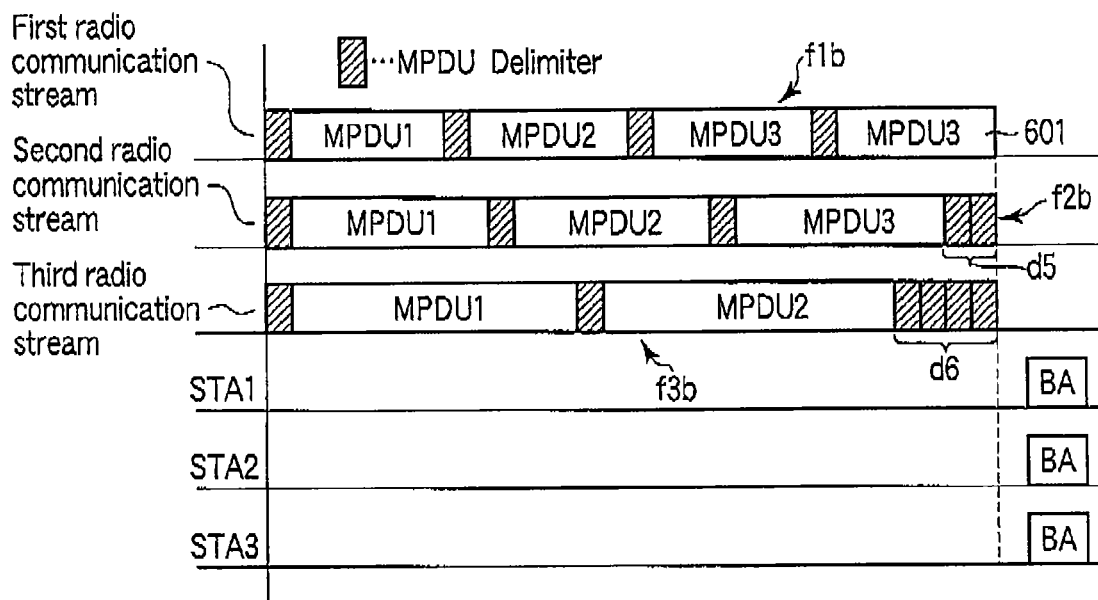


FIG. 6

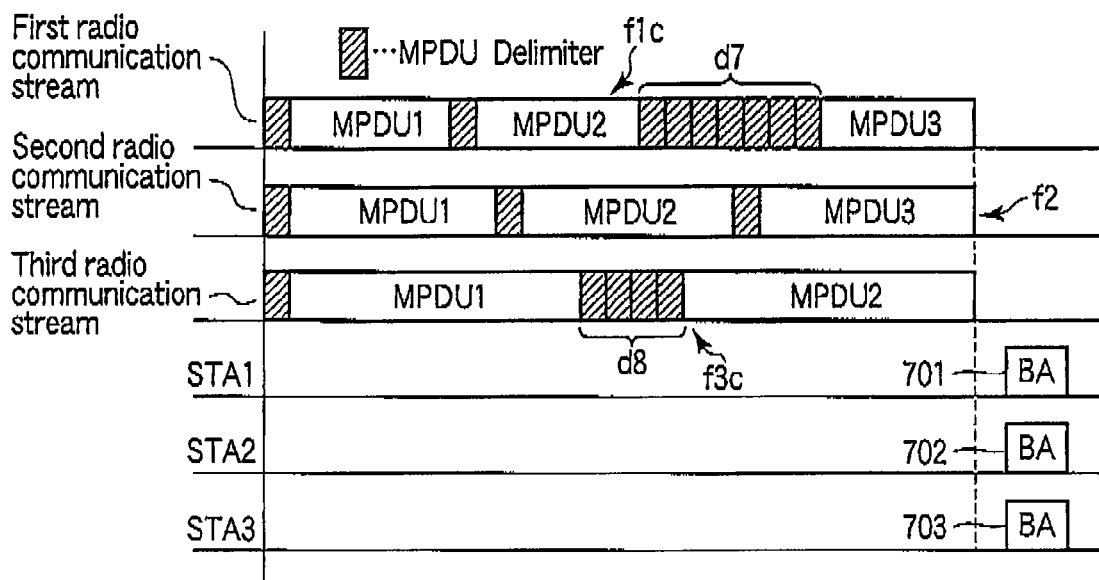


FIG. 7

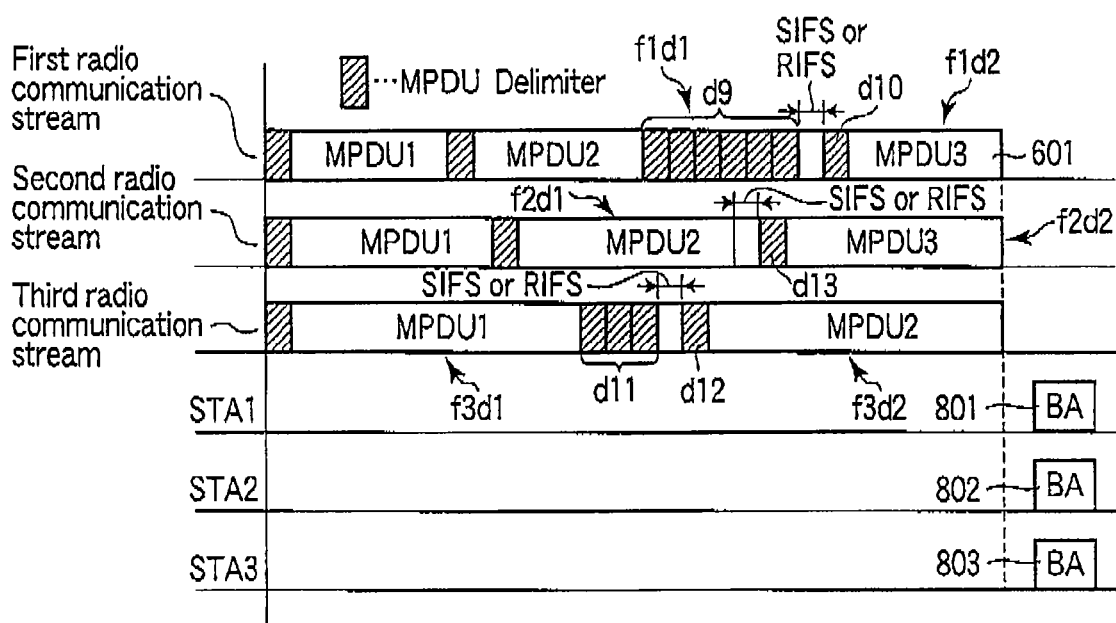


FIG. 8

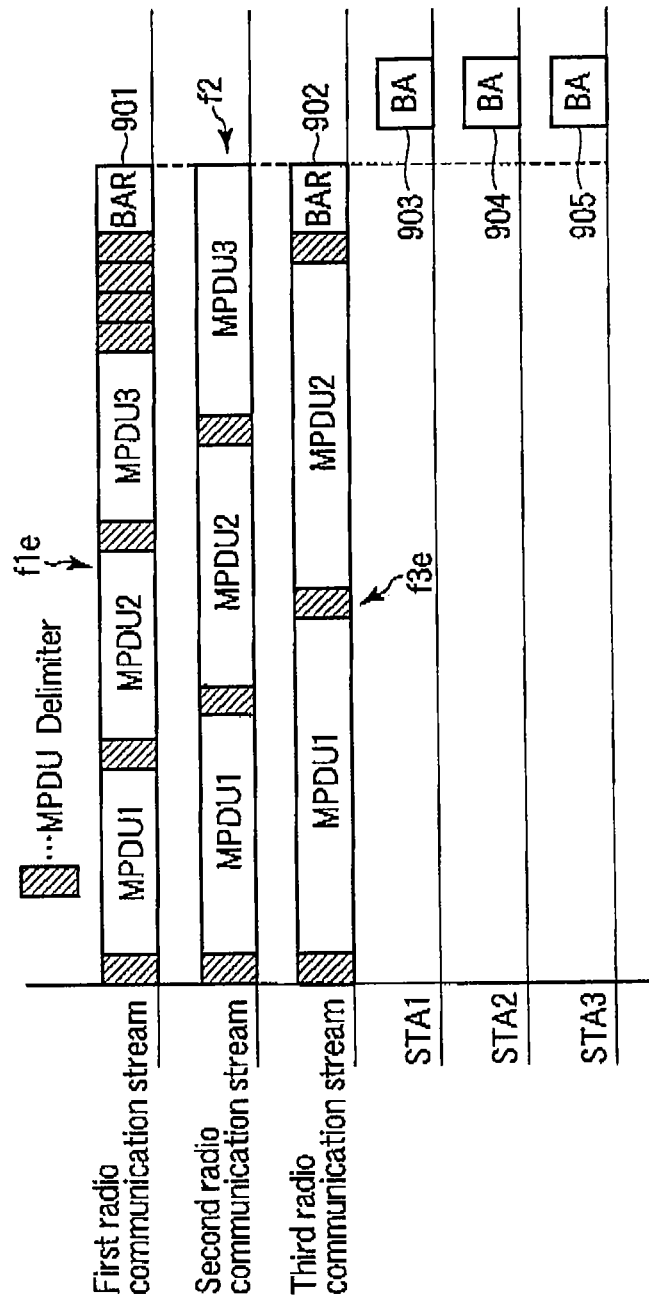


FIG. 9



# **RADIO COMMUNICATION DEVICE, METHOD, AND PROGRAM THAT CALCULATE TRANSMISSION TIME BASED ON DATA RATE**

## **CROSS-REFERENCE TO RELATED APPLICATIONS**

This application is based upon and claims the benefit of priority from prior Japanese Patent Application No. 2007-339941, filed Dec. 28, 2007, the entire contents of which are incorporated herein by reference.

## **BACKGROUND OF THE INVENTION**

### **1. Field of the Invention**

One embodiment of the invention relates to data transmissions when data is simultaneously transmitted to a plurality of radio communication devices in the case where a plurality of radio communication devices exist.

### **2. Description of the Related Art**

A multi-user Multiple Input Multiple Output (MIMO) has been recognized as a method for simultaneously performing MIMO communication among radio communication terminals of a plurality of users at the same time and in the same frequency band through evolution of a MIMO technique. While the multi-user MIMO communicates at the same time and in the same frequency band, it is impossible to perform transmissions and receptions at the same time. That is, while the multi-user MIMO may perform a plurality of MIMO transmissions at the same time in the same frequency band, it is presently impossible to simultaneously perform reception. Conversely, while a plurality of MIMO receptions may be performed at the same time and in the same frequency band, it is presently impossible to simultaneously perform transmission. It is impossible to separate transmissions and receptions from each other when they occur at the same time in a terminal. Therefore, in the multi-user MIMO, there is a need to separate transmission times from reception times.

As regards a technique for separating the transmissions from the receptions, for example, a technique of adjusting the timing of transmissions of transmission acknowledgement request frames (Ack Requests) so as to make the reception times of transmission acknowledgement frames (Acks) from a plurality of radio communication devices uniform when a plurality of frames differing in transmission time have been transmitted to the corresponding plurality of radio communication devices is disclosed in U.S. Patent Application Publication No. 2005/0147023. However, since the technique described in this patent document contains the transmissions of the Ack Requests as essential elements, overheads of times for transmitting the Ack Requests are generated, and this generation might lead to deterioration in throughput. In the case in which the Ack Requests are judged as errors owing to a radio environment and may not be received on reception terminal sides, even if transmission data has reached them, there is a need to retransmit the transmission data for the Ack Requests. This retransmission might lead to deterioration in throughput.

As regards another technique for separating the transmissions from the receptions, in the case in which one piece of data is divided and data transmission is performed by using a plurality of transmission channels at the same time, controlling the number of bytes of data frames to be divided to uniform transmission times of the data frames is disclosed in, for example, Jpn. Pat. Appln. KOKAI Publication No. 2004-350259. However, the technique described in this patent

document does not take any account of combining a plurality of data frames to transmit them when a plurality of data frames are stored in a transmission queue, i.e., transmitting the data frames by a frame aggregation system as described in IEEE 802.11n. In other words, in the technique described in the patent document, it is impossible to combine the transmissions of the data frames with a radio transmission system, such as the frame aggregation system in IEEE 802.11n, at a high rate and with high efficiency. In IEEE 802.11n, by which a standardization proposal is made as a radio communication technique at a high rate by the MIMO technique, a frame aggregation technique for combining a plurality of medium access control (MAC) frames into one physical (PHY) frame to transmit the PHY frame has been proposed as a technique of a MAC layer corresponding to acceleration of the PHY layer (e.g., refer to IEEE 802.11/D2.00).

## **BRIEF SUMMARY OF THE INVENTION**

According to an aspect of the invention, there is provided a radio communication device, comprising: a storage unit which stores a plurality of MAC frames for each of a plurality of destinations; a decision unit which decides the longest transmission time of transmission times needed to transmit the plurality of medium access control (MAC) frames for each of the plurality of destinations within a fixed period; a connection unit which connects the plurality of MAC frames; an addition unit which adds additional information to MAC frames each connected so as to be a frame length equivalent to a transmission time equal to the longest transmission time; a generation unit which generates a plurality of physical frames from the plurality of the connected MAC frames to which the additional information is added so as to be the frame length; and a transmission unit which transmits the plurality of physical frames at the same time.

## **BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING**

FIG. 1 is an exemplary block diagram depicting a configuration of a wireless LAN device of an embodiment of the invention;

FIGS. 2A and 2B are exemplary flowcharts depicting operations of the wireless LAN device of an embodiment of the invention;

FIG. 3 is an exemplary view depicting an example of frame exchanges in the case in which transmission times of transmission frames are not adjusted;

FIG. 4 is an exemplary view depicting an example of frame exchanges wherein an A-MAC Protocol Data Unit (MPDU) system of IEEE 802.11n is combined with multi-user MIMO communication by a wireless LAN device of a first embodiment;

FIG. 5 is an exemplary view depicting an example of frame exchanges wherein an A-MPDU system of IEEE 802.11n is combined with multi-user MIMO communication by a wireless LAN device of a second embodiment;

FIG. 6 is an exemplary view depicting an example of frame exchanges wherein an A-MPDU system of IEEE 802.11n is combined with multi-user MIMO communication by a wireless LAN device of a third embodiment;

FIG. 7 is an exemplary view depicting an example of frame exchanges wherein an A-MPDU system of IEEE 802.11n is combined with multi-user MIMO communication by a wireless LAN device of a fourth embodiment;

FIG. 8 is an exemplary view depicting an example of frame exchanges wherein an A-MPDU system of IEEE 802.11n is

combined with multi-user MIMO communication by a wireless LAN device of a fifth embodiment; and

FIG. 9 is an exemplary view depicting an example of frame exchanges wherein an A-MPDU system of IEEE 802.11n is combined with multi-user MIMO communication by a wireless LAN device of a sixth embodiment;

#### DETAILED DESCRIPTION OF THE INVENTION

Concrete embodiments of the invention will be described based on a wireless LAN communication system of IEEE 802.11. However, the wireless LAN communication system in IEEE 802.11n is only an example of a radio communication system to which an effect of the invention is applicable; i.e., the invention is also applicable to other radio communication systems. In the description hereinafter, a radio base station is referred to as an "access point (AP)", and a radio terminal or a radio communication device to be connected to the AP is referred to as a "station (STA)".

##### (First Embodiment)

A wireless LAN device **101** of the embodiment as shown in FIG. 1 comprises a transmission Queue **106** storing transmission data; a Queue Control unit **107** controlling a transmission destination and the number of items of transmission data from a data storage situation of the Queue **106**; a rate selection unit **108** deciding a transmission rate of a PHY layer by selecting any one of a prescribed plurality of transmission rates in response to a propagation environment; an aggregation processing unit **105** performing connection processing when a plurality of items of transmission data are connected to one frame and transmitting the frame; and a plurality of transmission and reception processing units **102**, **103**, **104** transmitting and receiving a plurality of streams by means of MIMO communication or multi-user MIMO communication.

The aggregation processing unit **105** includes a connection unit **1052** connecting a plurality of MAC frames; an addition unit **1053** adding additional information to the MAC frames each connected by the connection unit **1052** so as to be a frame length equivalent to a transmission time equal to the longest transmission time to be determined by the Control unit **107**; and a generation unit **1054** generating a plurality of physical frames for the plurality of destinations from the connected plurality of MAC frames to which additional information is added so as to be of a frame length.

According to the plurality of processing units **102**, **103**, **104**, the LAN device **101** may transmit a plurality of streams of the MIMO communication capable of transmitting a plurality of streams at the same time and in the same frequency band. That is, the LAN device **101** may perform multi-user MIMO communication; however even when adopting a communication system using a plurality of channels (multi-channel) to transmit the streams to a plurality of different channels at the same time, the processing units **102**, **103**, **104** are applicable.

In IEEE 802.11n, an A-MAC Service Data Unit (A-MSDU), which is a function for performing aggregation in MSDU units, and an A-MAC Protocol Data Unit (A-MPDU), which is a function for performing aggregation in MPDU units, are proposed. In A-MSDU, since one Header is added to a plurality of units, redundant headers may be reduced and the transmission time may be reduced, throughput may be improved, and power consumption saving may be achieved. In the A-MPDU, overhead parts such as a PHY header, Preamble SIFS time and an ACK frame added to each of a plurality of MPDU transmissions may be reduced, redundant transmission times may be reduced to improve the

throughput, and power consumption saving may be achieved. While the embodiment will describe the case of performing the A-MPDU of IEEE 802.11n as an example, the invention may be implemented in the case of adoption of other aggregation systems.

Operations of the wireless LAN device **101** of the embodiment will be described with reference to FIGS. 2-4. More specifically, the case in which the LAN device **101** performs data transmission processing to three STA **1**, STA **2**, STA **3** as transmission destinations will be described, as an example.

When the LAN device **101** generates the transmission data, the transmission data is stored in the transmission Queue **106** (Step 1). The Queue Control unit **107** decides the transmission destinations STA **1**, STA **2**, STA **3** and transmission channels from data information stored in the Queue **106** (Step 2). The Queue Control unit **107** notifies the transmission destinations and the decided transmission channels to the rate selection unit **108**.

The selection unit **108** recognizes a propagation situation of radio packets in transmission passages and decides the transmission rate and the maximum value of transmittable times on the basis of the propagation situation (Step 3). The maximum value of the transmittable times is obtained by calculating how long the transmission times become at a maximum depending on the propagation situation. As regards the maximum value of the transmittable time, a Transmission Opportunity (TXOP) Limit (a limit of channel use period) may be used.

The Control unit **107** collects information of the maximum transmission time for each transmission destination from the selection unit **108** (Step 4). Here, it is determined whether or not the individual maximum transmission times are equal to one another in transmitting the transmission data to streams or channels differing for each destination (Step 5). If each maximum transmission time differs, the shortest time is decided as the maximum transmission time (T1) for all streams (Step 6). Meanwhile, if the maximum transmission times of all streams are identical, this time is decided as the maximum transmission time (T1) for all streams (Step 7).

After deciding the time (T1), the Control unit **107** obtains the number of items of the transmittable data which is transmittable within the time (T1) from a storage amount and a transmission rate for each transmission destination STA **1**, STA **2**, STA **3** (Step 8). The embodiment shows the case in which the transmission Queue **106** stores a sufficiently large amount of transmission data. The case of a small data storage amount will be described in another embodiment.

Further, the Control unit **107** calculates transmission times of frames upon transmitting from each stream by combining the A-MPDU system of IEEE 802.11n with the multi-user MIMO communication from the number of the items of the transmission data decided in Step 8 and the transmission rate decided in Step 3 (Step 9).

The Control unit **107** determines whether or not the transmission times of the transmission frames to be transmitted from the respective streams are equal to one another (Step 10). As a result of mutual comparison of transmission times of the respective transmission frames, if the transmission times of all streams are equal to one another, the Control unit **107** performs transmission processing (Step 13).

However, usually, the respective stream may have different data lengths, numbers of pieces of transmission data, or transmission rates of the transmission data to be transmitted from the respective streams by the LAN device **101**. Therefore, it is not frequent for the transmission times of the transmission frames to be transmitted from all streams to be equal to one another in Step 10.

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If the transmission times of the transmission frames to be transmitted from all streams are different from one another, the Control unit **107** decides the longest transmission time (**T2**) (Step **11**).

For instance, if a transmission time of a frame **f2** to be transmitted to a second radio communication stream become the longest one as shown in FIG. **3**, that is, if a transmission time of a frame **f1** to be transmitted to a first radio communication stream and a transmission time of a frame **f3** to be transmitted to a third radio communication stream transmission is shorter than the transmission time of the frame **f2** to be transmitted to the second radio communication stream, the transmission time (**T2**) of the frame **f2** to be transmitted to the second radio communication stream is extracted.

The connection unit **1052** generates a frame by connecting MPDUs (MAC frames) read from the transmission Queue **106**. The addition unit **1053** adds a certain piece of redundant information (additional information) so that the transmission time of the frame **f1** to be transmitted to the first radio communication stream and the transmission time of the frame **f3** to be transmitted to the third radio communication stream become equivalent to the transmission time (**T2**) of the frame **f2** to be transmitted to the second radio communication stream (Step **12**).

More specifically, the addition unit **1053**, for example, as shown in FIG. **4**, connects an MPDU Delimiter in the A-MPDU system, which has been proposed in IEEE 802.11n, to each of the last tail of the frame **f1** for the first radio communication stream and the last tail of the frame **f3** for the third radio communication stream. One of the MPDU Delimiters (MPDU connection information field) is, for example, a fixed length, and the frame length is adjustable by connecting a plurality of the MPDU Delimiters each having the fixed length. In FIG. **4**, a frame formed by connecting an MPDU Delimiter **d1** (formed of six MPDU Delimiters) to the frame **f1** of FIG. **3** is indicated as a frame **f1'**, and a frame formed by connecting an MPDU Delimiter **d3** (formed of three MPDU Delimiters) to the frame **f3** of FIG. **3** is indicated as a frame **f3'**.

Therefore, as is clear from FIG. **4**, the transmission time of the frame **f1'** to be transmitted to the first radio communication stream and the transmission time of the frame **f3'** to be transmitted to the third radio communication stream become equal to the transmission time **T2** of the frame **f2** to be transmitted to the second radio communication stream. Thus, adjusting is implemented so that the transmission times of the frames of the respective streams become equal to one another. The generation unit **1054** generates a plurality of physical frames for a plurality of destinations (wherein differences in destination are equivalent to differences in stream). The transmission and reception processing units **102**, **103**, **104** transmit each of the plurality of frames generated from the generation unit **1054** at the same time and then transmit to all streams at the same time (Step **13**).

The case in which the aforementioned adjustment of the frame transmission times of the embodiment of the invention is not implemented will be described by referring to FIG. **3**. In this case, during the transmission of the frame **f2** to the second radio communication stream, the need to receive Block Ack (block transmission acknowledgement: BA) frames **301**, **303** returned from the STA **1** and the STA **3**, respectively, is posed. In the case in which the transmission processing and the reception processing cannot be performed at the same time in the multi-user MIMO system, even the different streams of the plurality of streams may not establish the communication, as is shown in FIG. **3**.

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Conversely, in the case of using the method of the embodiment of the invention, the adjustment is carried out so that the transmission times of the transmission frames to be transmitted from the respective streams become equal to one another.

Therefore, transmission completion times of the respective frames become uniform after the completion of the transmission processing to all streams, and the radio communication device **101** can receive Block Ack frames **401**, **402**, **403** returned from STA **1**, STA **2**, and STA **3**, as is shown in FIG. **4**.

It is not necessary for receiving the Block Ack frames **401**, **402**, **403** at strictly the same time. There is a case in which the transmission times of the transmission frames of the respective streams cannot be perfectly uniform with one another, in such a case; it is sufficient if the deviance of the transmission times is suppressed within an SIFS time. Anyway, it is sufficient if occurrences of the transmission processing and the reception processing at the same time can be avoided.

A connection method for the MPDU Delimiters in the case of the use of the MPDU Delimiters so as to make the transmission time of the transmission frame equivalent to the transmission time of the specified frame will be described.

While the former IEEE 802.11n standards have defined a transmission of a single MPDU Delimiter (MAC frame), in IEEE 802.11n, a plurality of MPDUs are combined into one frame to create the A-MPDU frame, and such an A-MPDU frame transmits a plurality of MPDUs at the same time. At this moment, the wireless LAN device adds the MPDU Delimiters at Heads of the respective MPDUs, and frame lengths of the MPDUs connected just after are described in MPDU length fields in the MPDU Delimiters to set them as identifiers when the respective MPDUs are separated.

In the embodiment, to uniform the transmission times of the transmission frames of the respective streams, the addition unit **1053** connects only the MPDU Delimiters (**d1**, **d3**) not including the following MPDUs, as shown in FIG. **4**.

Accordingly, in the embodiment, it becomes possible to make the transmission times of the transmission frames of the respective streams equivalent to one another without going counter to the A-MPDU system in IEEE 802.11n.

Even when the wireless LAN communication standard in the multi-user MIMO system for performing the MIMO communication with the plurality of user MIMO terminals at the same time and in the same frequency band while, for instance, the wireless LAN device **101** operates as an access point, and synchronizes with each of the plurality of user MIMO terminals to be accommodated at the access point is established as new standards after IEEE 802.11n, according to the transmission system of the embodiment of the invention, backward compatibility may be maintained as mentioned below.

For instance, although the LAN device **101** establishes the communication in the multi-user MIMO system, the LAN device **101** assumes a situation in which wireless LAN terminals compatible with IEEE 802.11n standards supporting the MIMO communication but not supporting the multi-user MIMO system are included in the plurality of the transmission destination terminals. For instance, the STA **3** is assumed to be a wireless LAN terminal compatible with such an IEEE 802.11n in FIG. **4**. In this embodiment of the invention, after connecting the plurality of MPDUs, the wireless LAN device adjusts the transmission times of the transmission frames in the method compatible with the A-MPDU system in IEEE 802.11n. More specifically, the LAN device describes zero in the MPDU length field in the MPDU Delimiter to make the connections and then adjusts the transmission times. Therefore, the STA **3** that is the wireless LAN terminal which is

compliant with IEEE 802.11n standards may normally receive the frames through the reception processing based on IEEE 802.11n standards.

The STA 3 that is the wireless LAN terminal which is compatible with IEEE 802.11n standards also may operate the multi-user MIMO communication terminal with the intention of delaying the return time of the Block Ack in the multi-user MIMO communication. Accordingly, the multi-user MIMO communication may maintain the backward compatibility with IEEE 802.11n standards.

While the embodiment has described the radio communication in the multi-user MIMO system using the plurality of streams, the radio communication method to which the invention can be applied is not limited only to the multi-user MIMO system. The invention is also applicable to a communication form in a multi-channel environment in which a plurality of radio channels are used in the same way as that of the plurality of streams of the embodiment.

As mentioned above, according to the embodiment of the invention, in the multi-user MIMO communication and in the multi-channel communication, the wireless LAN device may efficiently separate the transmission times from the reception times. Since the frame aggregation technique is used, the throughput is not deteriorated. Further, the backward compatibility with IEEE 802.11n standards may be maintained.

(Second Embodiment)

Since a second embodiment is a modified example of the first embodiment, parts differing from those of the first embodiment will be mainly described. The second embodiment differs from the first embodiment in a method for adjusting frame transmission times. The configuration of a wireless LAN device of the second embodiment is the same as that shown in FIG. 1, which has been described in the first embodiment. Operations of the LAN device of this embodiment are the same as those of the first embodiment from Step 1 to Step 11 of FIG. 2. That is, also in the second embodiment, it is assumed that the transmission time of the frame 2 for the second radio communication stream in FIG. 2 is extracted as the longest transmission time (T2) (Step 11). At this moment, as is shown in FIG. 1, the transmission time of the frame f1 to be transmitted to the first embodiment and the transmission time of frame f3 to be transmitted to the third radio communication stream have become shorter than the longest transmission time T2 in accordance with the difference in the MPDU length of each stream, and in the number of storages and transmission rates of the transmission Queue 106.

As shown in FIG. 5, also in the second embodiment, to uniform the transmission times in the same way as in the first embodiment, the addition unit 1053 adds the MPDU Delimiter behind the last MPDU of each piece of the transmission data; however especially in the second embodiment, the number of the MPDU Delimiters to be added is set to "1", and following the MPDU Delimiters, and connects Quality of Service (QoS) Null frames to uniform the transmission times (Step 12).

Therefore, as is clear in FIG. 5, a transmission time of a frame f1a to be transmitted for the first radio communication stream and a transmission time of a frame f3a to be transmitted for the third radio communication stream become equal to the transmission time T2 of the frame f2 to be transmitted for the second radio communication stream. Thus, after adjusting so that the transmission time of the frame to each stream becomes equal, all streams are transmitted at the same time (Step 13).

The QoS Null frame defined by the existing IEEE 802.11e has a fixed length having a MAC Header and a cyclic redundancy code (CRC). Leaving the QoS Null frame as it is, if the

frame lengths of the first and the third radio communication streams are different from each other, the frame transmission times may not be uniformed. Therefore, as shown in FIG. 5, a Frame Body 502 is inserted for padding between a Header 501 and a CRC 503, and the length of the Frame Body 502 is made variable. Thereby, even if the transmission times of the respective streams are uneven, using such a QoS Null frame which is variable in length enables adjusting the transmission times of the frames.

In a method of the second embodiment, even if the length of the Frame Body is set to zero, the addition of the QoS Null frame makes the frame long in length, and poses the possibility of the case in which the transmission time of the frame exceeds the longest transmission time (T2). At this time, if the transmission times of the frames are not longer than the length of transmittable time (T1) for all streams, the value of the transmission times of the frames are redefined to T2. It is preferable to adjust the transmission times of the transmission frames in all streams so that the transmission times become equal to the newly defined longest transmission time T2. If the transmission times of the transmission frames of all frames exceed the longest transmittable time (T1), a method can be used, which should not use the QoS Null frame, but may connect the MPDU Delimiters in the same way as the first embodiment and uniform the transmission times.

Even in the aforementioned second embodiment, similarly to the above first embodiment, in the communication using the multi-user MIMO communication and the communication using the multi-channel, the wireless LAN device may efficiently separate the transmission times and the reception times without causing deterioration in throughput, and may maintain the backward compatibility with IEEE 802.11n standards.

(Third Embodiment)

Since a third embodiment is a modified example of the first embodiment, the third embodiment will mainly describe parts differing from those of the first embodiment. The third embodiment is different from the first embodiment in a method for adjusting the frame transmission times. A configuration of a wireless LAN device of this embodiment is the same that is shown in FIG. 1 described in the first embodiment. Operations of the LAN device of this embodiment are the same as those of the first embodiment from Step 1 to Step 11 of FIG. 2. That is, also in the third embodiment, it is assumed that the transmission time of the frame 2 for the second radio communication stream in FIG. 2 is extracted as the longest transmission time (T2) (Step 11). At this moment, as is shown in FIG. 3, the transmission time of the frame f1 to be transmitted for the first embodiment and the transmission time of frame f3 to be transmitted for the third radio communication stream have become shorter than the longest transmission time T2 in accordance with the difference in the MPDU length of each stream, and in the number of storages and translation rates of the transmission Queue 106.

As shown in FIG. 6, even in the third embodiment, similarly to the first embodiment, to uniform the transmission times, the addition unit 1053 adds the MPDU Delimiter behind the last MPDU of each piece of transmission data; however, especially in the third embodiment, for the frames for the first radio communication stream, makes a copy of an MPDU 3 that is the last MPDU in the A-MPDU, adds the MPDU Delimiter, and adds a copy 601 of the MPDU behind the A-MPDU to form a frame f1b.

In this embodiment, as is clear from FIG. 6, in the first radio communication frame, the transmission time of the frame f1b becomes longer than the longest transmission time (T2). If the transmission time of the frame f1b is not longer than the

maximum transmission time (T1) for all streams, the value of the transmission time of the frame f1b is redefined as T2.

As regards the second radio communication stream, the addition unit 105 adjusts the transmission times of the frames so as to make the transmission times of the frames equal to the newly defined transmission time T2 by connecting a plurality of MPDU Delimiters d5 to the frames, and then, forms the frame f2b. As regards the third radio communication stream, the addition unit 105 adjusts the transmission times of the frames so as to make the transmission times of the frames equal to the newly defined transmission time T2 by connecting a plurality of MPDU Delimiters d6 to the frames, and then, forms the frame f3b. Thereby, the transmission times of all streams are uniformed (Step 12).

Thus, after adjusting the transmission times so as to uniform the transmission time of the frame of each stream, the transmission processing is performed for all streams at the same time (Step 13).

A method may be used which uniformes the transmission times by connecting the MPDU Delimiters in the same way as that of the first embodiment without adding the copy 601 of the MPDU if the transmission time of the frame f1b exceeds the maximum transmission time (T1) for all streams.

Also in the above third embodiment, similarly to the aforementioned first embodiment, in the communication using the multi-user MIMO communication and the communication using the multi-channel, the wireless LAN device does not pose the danger of deterioration in throughput, and may efficiently separate the transmission times and the reception times. Further, the LAN device may maintain the backward compatibility with IEEE 802.11n standards.

#### (Fourth Embodiment)

Since a fourth embodiment is a modified example of the first embodiment, the fourth embodiment will mainly describe the parts differing from those of the first embodiment. The fourth embodiment is different from the first embodiment in a method for adjusting the frame transmission times. A configuration of a wireless LAN device of this embodiment is the same as that shown in FIG. 1 described in the first embodiment. Operations of the LAN device of this embodiment are the same as those of the first embodiment from Step 1 to Step 10 of FIG. 2. That is, also in the fourth embodiment, it is assumed that the transmission time of the frame 2 for the second radio communication stream in FIG. 2 is extracted as the longest transmission time (T2) (Step 11). At this moment, as is shown in FIG. 3, the transmission time of the frame f1 to be transmitted to the first embodiment and the transmission time of frame f3 to be transmitted to the third radio communication stream have become shorter than the longest transmission time T2 in accordance with the difference in the MPDU length each stream, and in the number of storages and translation rates of the transmission Queue 106.

As shown in FIG. 7, also the fourth embodiment adjusts the time transmissions similarly to the first embodiment. Especially in the fourth embodiment; however, as regards the frames for the first radio communication stream, the addition unit 1053 inserts a plurality of MPDU Delimiters d8 in front of the last MPDU (namely, MPDU 3) in the plurality of MPDUs and forms the frame f1c. Thereby, the wireless LAN device makes the transmission time of the frame f1 to be transmitted to the first radio communication stream and the transmission time of the frame f3c to be transmitted to the third radio communication stream uniform with the transmission time (T2) of the frame f2 to be transmitted to the second radio communication stream (Step 12).

Thus, after adjusting the transmission time of the frame of each stream to be uniform with one another, the transmission processing is performed for all streams at the same time (Step 13).

According to the fourth embodiment, by using the MPDU Delimiters, the wireless LAN device may uniform the transmission time of each stream while maintaining the backward compatibility with IEEE 802.11n standards, and also may uniform the transmission completion time of the MPDU to be transmitted from each stream.

Thus, the wireless LAN device may return Block Ack frames 701, 702, and 703 that are transmission acknowledgement frames from the transmission destination terminal of each stream at the same time.

#### (Fifth Embodiment)

Since a fifth embodiment is a modified example of the fourth embodiment, the fifth embodiment will mainly describe parts differing from those of the first and the fourth embodiments. The fifth embodiment is different from the first embodiment in a method for adjusting the frame transmission times. A configuration of a wireless LAN device of this embodiment is the same as that shown in FIG. 1 described in the first embodiment. Operations of the LAN device of this embodiment are the same as those of the first embodiment from Step 1 to Step 10 of FIG. 2. That is, also in the fifth embodiment, it is assumed that the transmission time of the frame 2 for the second radio communication stream in FIG. 2 is extracted as the longest transmission time (T2) (Step 11). At this moment, as is shown in FIG. 3, the transmission time of the frame f1 to be transmitted to the first embodiment and the transmission time of frame f3 to be transmitted to the third radio communication stream have become shorter than the longest transmission time T2 in accordance with the difference in the MPDU length of each stream, and in the number of storages and translation rates of the transmission Queue 106.

As shown in FIG. 8, also in the fifth embodiment, similarly to the fourth embodiment, although the wireless LAN device adjusts the time transmissions, especially in the fifth embodiment, as regards the first radio communication stream, the addition unit 1053 inserts the same number of MPDU Delimiters as in the fourth embodiment so as to leave a space of an SIFS period or an RIFS period in front of an MPDU Delimiter d10 immediately in front of the last MPDU 3. Thereby, the LAN device separates the A-MPDU frame having the MPDU 1 and the MPDU 2 from the last MPDU 3, and transmits two physical frames; a frame f1d1 and a frame f1d2, respectively. Also, as regards the second radio communication stream in a similar way, the addition unit 1053 leaves a space of the SIFS period or the RIFS period in front of an MPDU Delimiter d13 immediately in front of the last MPDU 3. Thereby, the LAN device transmits the frames as a frame f2d2 having the MPDU 1 and the MPDU 2, and as a frame f2d2 having the MPDU 3. As regards the third radio communication stream, in a similar way, the addition unit 1053 leaves a space of the SIFS period or the RIFS period in front of an MPDU Delimiter d12 immediately in front of the last MPDU 2. Thereby, the LAN device transmits the frames as a frame f3d1 having the MPDU 1 and the MPDU Delimiter d11 and as a frame f3d2 having the MPDU 2.

In the fifth embodiment, aggregation frames including a plurality of MPDUs in the A-MPDU system may use physical frames (e.g., frame f1d2, f2d2, f3d2) of the space of the SIFS period or the space of the RIFS period, and may be configured of frames not including the MPDU Delimiters so as to transmit the stream including only MPDUs.

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Since the A-MPDU system connects and transmits a plurality of MPDUs, the frame length thereof becomes long, resulting in the problem of a possibility of transmission errors in the latter half of the frame increases. To avoid this problem, while the conventional A-MPDU system controls so that the frame length thereof does not become longer than a prescribed length, in this embodiment, separating the MPDU into two or more physical frames enables avoiding the problem that the latter half of the frame in the S-MPDU system leads to a transfer error.

Thus, after adjusting the streams so as to uniform the transmission times of the frames of the respective streams, the LAN device transmits all streams at the same time (Step 13).

According to the fifth embodiment, using the MPDU Delimiters enables uniforming the transmission times of the respective streams while maintaining the backward compatibility with IEEE 802.11n, and also enables uniforming the transmission completion times of the MPDUs to be transmitted from the respective streams. Therefore, it makes it possible to return at the same time Block Acks 801, 802 and 803 that are transmission acknowledgement frames from transmission destination terminals of the respective streams.

Further, according to the fifth embodiment, since the plurality of MPDUs may be separated into two or more physical frames, the wireless LAN device may lengthen the transmission time of each stream while preventing the problem such that the physical frame length becomes long, which increases the possibility of transmission errors.

(Sixth Embodiment)

Since a sixth embodiment is a modified example of the first embodiment, the sixth embodiment will mainly describe parts differing from those of the first embodiment. The sixth embodiment is different from the first embodiment in a method for adjusting the frame transmission times. A configuration of a wireless LAN device of this embodiment is the same as that shown in FIG. 1 described in the first embodiment. Operations of the LAN device of this embodiment are the same as those of the first embodiment from Step 1 to Step 10 of FIG. 2. That is, also in the sixth embodiment, it is assumed that the transmission time of the frame 2 for the second radio communication stream in FIG. 2 is extracted as the longest transmission time (T2) (Step 11). At this moment, as is shown in FIG. 3, the transmission time of the frame f1 to be transmitted to the first embodiment and the transmission time of frame f3 to be transmitted to the third radio communication stream have become shorter than the longest transmission time T2 in accordance with the difference in the MPDU length of each stream, and in the number of storages and translation rates of the transmission Queue 106.

Also in the sixth embodiment, similarly to the first embodiment, while the addition unit 1053 connects the MPDU Delimiters in the A-MPDU system proposed in IEEE 802.11n to the last tail of the frame in the first radio communication stream and the last tail of the frame in the third radio communication stream, respectively, especially in the sixth embodiment, the addition unit 1053 connects Block Ack Request (block transmission acknowledgement request) frames 901 and 902 to the last tail of the frame in the first radio communication stream and the last tail of the frame in the third radio communication stream, respectively. Thereby, the transmission times of all the streams are uniformed (Step 12).

In the sixth embodiment, similarly to the fifth embodiment, the addition unit 1053 may leave the space of the SIFS period or the RIFS period in front of the last MPDU or the MPDU Delimiters immediately in front of a BAR. The wireless LAN device may perform transmission processing as two physical frames separating the A-MPDU frame from the LAST

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MPDU or the BAR. In this case, an aggregation frame including a plurality of MPDUs in the A-MPDU system may be used, and a stream may be configured as frames not including any MPDU Delimiter so as to transmit the stream only by the MPDU. The A-MPDU system has the problem that the frame length becomes long because of transmission involving connecting a plurality of MPDUs; as a result, the possibility of transmission errors in the latter half of the frame increases. To avoid this problem, conventionally, the frame length in the A-MPDU system is controlled so as not to become longer than a prescribed length, thus it becomes possible to avoid the problem that the latter half of the frame in the A-MPDU system e transmission error by separating the frame into two or more physical frames.

Thus, after adjusting so as to uniform the transmission times of the frames for the respective streams, the transmission processing for all the streams is performed at the same time (Step 13).

According to the sixth embodiment, using the MPDU Delimiters enable uniforming the transmission times of the respective streams while maintaining the backward compatibility with IEEE 802.11n standards, and also enables uniforming transmission completion times of a BAR 901 of a frame f1e to be transmitted from the first radio communication stream, of a MPDU 3 of a frame f2 to be transmitted from the second radio communication stream, and of a BAR 902 of a frame f3e to be transmitted from the third radio communication stream.

Accordingly, it makes it possible to return Block Ack frames 903, 904, and 905 that are transmission acknowledgement frames from transmission destination terminals of the respective streams at the same time.

Further, the sixth embodiment makes it possible to lengthen the transmission times of the respective streams while preventing the problem that the lengths of the physical frames become long and the possibility of transmission errors increases when the plurality of MPDUs are composed of two or more physical frames.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A radio communication method, comprising:
  - connecting a set of MAC frames into a first unit, the set of MAC frames having a same destination;
  - calculating each of a plurality of second transmission times based on a length of the first unit and a data rate, the first unit and the data rate corresponding to one of a plurality of physical frames, the plurality of physical frames being transmitted simultaneously and having different destinations;
  - deciding a first transmission time to be longest among the plurality of second transmission times;
  - adding a second unit to the first unit to construct a third unit if a corresponding one of the second transmission times is shorter than the first transmission time, a transmission time of the third unit resulting in a time equivalent to the first transmission time;
  - generating one of the plurality of physical frames from the third unit and generating one of the plurality of physical

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frames from the first unit if corresponding one of the second transmission times is equal to the first transmission time; and

transmitting a set of physical frames simultaneously, where each physical frame in the set of the physical frames has a different destination.

2. A radio communication method, comprising:

generating a plurality of first units, each of the first units being generated by connecting a set of MAC Protocol Data Units (MPDUs) and transmission destinations of MPDUs within a same one of the first unit being identical;

selecting a part of the plurality of first units as a first set to be transmitted simultaneously, the first units in the first set each having a different MPDU transmission destination;

deciding a longest one among a plurality of second transmission times as a first transmission time, by calculating the plurality of second transmission times on the first units in the first set, where each of the second transmission times is a physical frame transmission time carrying each one of the first units in the first set and is calculated based on a length of each one of the first units and a data rate assigned to the physical frame transmission times carrying each one of the first units;

adding a variable second unit to each one of the first units in the first set if a corresponding one of the second transmission times to each one of the first units in the first set is shorter than the first transmission time,

each set of the one of the first units in the first set and the added variable second unit forming one of a plurality of third units,

each physical frame transmission time carrying each of the plurality of third units being calculated based on a length of each of the plurality of third units and a data rate assigned to each of the physical frames carrying each of the plurality of third units,

the data rate of each of the plurality of third units being equal to the data rate of the corresponding one of the first units in the first set,

each of the physical frame transmission times carrying each of the plurality of third units resulting in a time equivalent to the first transmission time, and

the first set changed to a second set of the first units from the first set which are to be transmitted in the first transmission time and the plurality of third units resulting in being transmitted in same physical frame transmission time with the first transmission time;

generating a plurality of physical frames, each of the plurality of physical frames being generated from each one of the first and third units in the second set; and

transmitting the plurality of physical frames simultaneously.

3. A radio communication apparatus, comprising:

a first generating device which generates a plurality of first units, each of the first units being generated by connecting a set of MAC Protocol Data Units (MPDUs) and transmission destinations of MPDUs within a same one of the first unit being identical;

a selection device which selects a part of the plurality of first units as a first set to be transmitted simultaneously, the first units in the first set each having a different MPDU transmission destination;

a decision device which decides a longest one among a plurality of second transmission times as a first transmission time, by calculating the plurality of second transmission times on the first units in the first set, where

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each of the second transmission times is a physical frame transmission time carrying each one of the first units in the first set and is calculated based on a length of each one of the first units and a data rate assigned to a physical frame carrying each one of the first units;

an addition device which adds a variable second unit to each one of the first units in the first set if a corresponding one of the second transmission times to each one of the first units in the first set is shorter than the first transmission time,

each set of the one of the first units in the first set and the added variable second unit forming one of a plurality of third units,

each physical frame transmission time carrying each of the plurality of third units being calculated based on a length of each of the plurality of third units and a data rate assigned to each of the physical frames carrying each of the plurality of third units,

the data rate of each of the plurality of third units being equal to the data rate of the corresponding one of the first units in the first set,

each of the physical frame transmission times carrying each of the plurality of third units resulting in a time equivalent to the first transmission time, and

the first set changed to a second set of the first units from the first set which are to be transmitted in the first transmission time and the plurality of third units resulting in being transmitted in same physical frame transmission time with the first transmission time;

a generation device which generates a plurality of physical frames, each of the plurality of physical frames being generated from each one of the first and third units in the second set; and

a transmission device which transmits the plurality of physical frames simultaneously.

4. The apparatus according to claim 3, wherein the transmission device transmits the plurality of physical frames simultaneously in accordance with a multi-user Multiple Input Multiple Output (MIMO) system.

5. The apparatus according to claim 3, wherein the transmission device transmits the plurality of physical frames in accordance with multi-channel communication which communicates with a plurality of radio terminals by using a plurality of channels simultaneously.

6. The apparatus according to claim 3, wherein the plurality of first units contain delimiter fields, each of the delimiter fields in the first units are located in front of each of the MPDUs, and wherein the addition unit adds the delimiter fields as the variable second unit to the first unit.

7. The apparatus according to claim 6, wherein the variable second unit is added after the plurality of first units.

8. The apparatus according to claim 3, wherein the variable second unit is a Quality of Service (QoS) Null frame having a variable-length Frame Body and the QoS Null frame is added after the plurality of first units.

9. The apparatus according to claim 3, wherein the variable second unit is a copy of one of the MPDUs which is located last in the plurality of first units.

10. The apparatus according to claim 3, wherein the variable second unit is inserted between the MPDUs generating each one of the plurality of first units to make transmission completion times of the MPDUs located at an end of each one of the plurality of first units in the second set which are to be transmitted in the first transmission time and the plurality of third units in the second set resulting in being transmitted in a same physical frame transmission time with the first transmission time to be the same.

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**11.** The apparatus according to claim **3**, wherein the variable second unit is a frame space.

**12.** The apparatus according to claim **3**, wherein transmission acknowledgement request frames are appended to the variable second unit.

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**13.** The apparatus according to claim **3**, further comprising an antenna, wherein the transmitting device is configured to transmit the plurality of physical frames via the antenna.

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